NBS TECHNICAL NOTE 884

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Calibration of Unrecorded Low and Medium Density Type Magnetic Disk Pack Surfaces

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Calibration of Unrecorded Low and Medium Density Type Magnetic Disk Pack Surfaces

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This publication describes the design requirements and the operation of the NBS test bed that is used for calibrating unrecorded magnetic disk pack surfaces for low and medium density use. The signal level calibration is made with respect to a reference level that is derived from the NBS Standard Amplitude and Data Reference Surfaces that are held in repository at NBS. The techniques for calibrating the measurement system with the NBS repository Reference Surfaces and the calibration of candidate reference disks are described in detail.

Key words: Calibration factor; computer amplitude reference; computer storage media; disk calibration; disk pack; magnetic disk; standard reference surface; unrecorded disk surface.

1. Introduction

Magnetic disk packs are used with electronic computers for high speed random access storage of digital information. The magnetic characteristics of disk pack surfaces have been specified in national and international standards to help achieve unrecorded disk pack interchange between disk storages and associated information processing systems. NBS and the American National Standards Institute (ANSI) have agreed to the establishment of Standard Reference Surfaces and a disk calibration service in support of disk standardization. These Standard Reference Surfaces are held in repository at NBS, and are used for calibrating the test bed which is then used for measuring the relative signal amplitude characteristics of the candidate disk surfaces that are submitted by industry. These calibrated secondary reference surfaces are then used by industry as their in-house primary standards for controlling disk characteristics between given tolerances.

The ANSI X3 Committee presented a low density (1100 bits per inch) Standard Amplitude Reference Surface to be held in repository and to be used for calibrating low density surfaces by NBS. For calibrating medium density (2200 bits per inch) surfaces, both the Amplitude Standard and a Data Standard Reference Surface are required. Medium density disk packs are used in drives that employ data type heads, but the signal amplitude qualities of these surfaces can be more completely characterized by calibrating them with both an amplitude and a data test head. A number of medium density candidate amplitude and data reference surfaces were submitted to NBS by several industry manufacturers. Read-back signal amplitude measurements were then made of these candidate surfaces using a group of amplitude and data test heads. The values which were derived were submitted to the ANSI X3B7 Committee. The measured values obtained by industry at their laboratories when using their own disks and heads were also submitted to X3B7. Using these submissions, X3B7 established the values of standard amplitude and standard data references for given test conditions as shown in the following table:

Surface Density	Test Head Type	Tunnel/Straddle Erase Current	Track Location	Frequency megahertz	Standard Amplitude/ Data Reference millivolts
Low	amplitude	on	000	0.625	11.3
Low	amplitude	on	200	0.625	6.6
Low	amplitude	on	200	1.25	3.5
Medium	amplitude	off	000	0.625	11.5
Medium	amplitude	off	200	0.625	7.0
Medium	data	on	200	1.25	3.8
Medium	data	on	200	2.5	1.5

A Medium Density Standard Amplitude Reference and several Data Reference Surfaces were selected by NBS from the candidates. Groups of working reference surfaces for each density were also selected. These surfaces were chosen on the basis of their read-back signal amplitudes relative to those of the established standard amplitude references, their signal envelope uniformity and smoothness, and the absence of dropouts or dropins within the tests areas. Their resolution values are within the range specified by the ANSI and ISO disk pack standards. A group of amplitude and data reference heads were also selected on the basis of their signal amplitude, resolution, and resonant frequency characteristics as specified in the ANSI and ISO standards. These primary and working standard reference surfaces and test heads are maintained in repository at NBS. Periodically, the signal amplitude characteristics of these surfaces and heads are measured on the NBS test bed. Any change in the characteristics of a disk or head would indicate possible damage or serious change to the head or disk, and would initiate a search for a replacement. To date, no change has been noted in any of the disks or heads held in repository for the past two years.

2. General Description of the Disk Calibration Services

Candidate disks are calibrated on the basis of the read-back signal amplitude characteristics of their surface test areas relative to those that are obtained from the Standard Reference Surface. The test areas are located on track 000 (outer diameter) and on track 200 (inner diameter). The test areas are each 225 microseconds in length, starting 50 microseconds from a scribe mark on the surface with the disk rotating at 2400 rpm. The write current level, frequency, and tunnel or straddle erase conditions to be used for recording on the test area are specified for each test condition. The NBS test bed and the instrumentation are first calibrated to the Standard Amplitude Reference level using the Standard Reference Surface and test head on the test bed. The candidate disk is then substituted for the Standard Reference Surface and is recorded in a similar fashion. The Measured Amplitude of the candidate disk test area is then derived from observations made of the read-back signal. The method of deriving the Measured Amplitude is described in section 4.2.b. The Calibration Factor is then calculated as the ratio of the Standard Amplitude Reference value to that Measured Amplitude of the candidate disk. Several calibrations are made on each disk using different heads. Any erroneous readings are detected by this process.

A data base of measurements derived from the primary surfaces and the families of working reference surfaces and heads is being maintained in order to determine the precision of the measurements. From this data base, the computed standard deviation σ for each disk Calibration Factor is recalculated as the number of measurements n increases. The Calibration Factor of each candidate disk has an associated Uncertainty Factor of 3σ that is the current largest value of 3σ computed from the NBS family of reference surfaces. Assuming a normal distribution, the chance of any single error having an absolute value greater than three times the computed standard deviation 3σ is one in four hundred. The Uncertainty Factor is an index of precision for the calibration process, equipment, and the phenomenon that is being measured. A candidate disk is reported to have a Calibration Factor and an Uncertainty Factor, i.e., $C_D \pm 3\sigma$, for every test condition.

The reported Calibration Factor for any disk is the average value of several independent calibrations made over a period of time. By calibrating the candidate disk several times, the probability of a single observational error biasing the resulting Calibration Factor is reduced. Constant system errors are not eliminated by repetitive calibrations. Uniformly occurring measurement errors will not affect the validity of the reported Calibration Factor. The designation of plus or minus 3σ as the precision of the calibration service results in a conservative estimate of precision from the data base.

3. Component Parts of the Measurement System

3.1. Disks

Disks that are used in the various types of disk packs usually consist of an aluminum substrate which is coated with a magnetic oxide formulation. The thickness and formulation of the coating depends upon the application of the disk, i.e., low, medium, or high density use. The mixture is spin-coated onto the aluminum substrate so as to produce a wedge-shaped coating whose thickest section is located toward the outer diameter of the disk. This is

done in order to assure that the ratio of the read head signal levels which are produced by the outer disk track and the inner disk track is approximately two to one. The read system electronics can then easily be designed to operate within this range. The double frequency encoding/decoding system of recording is employed. In this mode of recording, a flux reversal takes place every clock time. A flux reversal also occurs between clock times for every "one" bit. The coating formulation and the head design are also controlled to produce a head signal at the basic frequency which is approximately twice the output at twice the basic frequency (all "ones" pattern). There are two types of surfaces used for low and medium density recording. The low density (1100 bpi) is used in the six-high disk pack. The medium density (2200 bpi) is used in the eleven-high disk pack and the single-disk front and top loading cartridges. In recent years, some manufacturers are utilizing the medium density type, rather than the low density type, in the six-high disk pack.

3.2 Heads

The IBM 2316 (2311 type) amplitude test head and the IBM 2314 data test head (or their equivalents) have been specified in the ANSI and ISO standards as being acceptable type test heads for the appropriate disk type testing. The 2316 amplitude test head that is used with the six-high disk pack has a stainless steel pad, is center-pivot loaded, and flies above the disk surface at a height of approximately 100 microinches. There are two tunnel erase windings on the head pad immediately following the write winding. The tunnel erase gaps are parallel to, and overlap each end of, the write gap. When written with tunnel erase current off, the track width of an amplitude test head is 0.201 ± 0.0025 mm (0.0079 ± 0.009 inches). When written with tunnel erase current on, the track width is 0.140 ± 0.013 mm (0.0055 ± 0.0005 inches). The 2314 data test head that is used with the eleven-high disk pack and the single-disk cartridges has a ceramic pad, is center-pivot loaded, and flies above the surface at a height of approximately 75 microinches. There are two straddle erase windings on the head pad immediately following the write windings. The straddle erase gaps are perpendicular to, and are located at the ends of, the write gap. When written with straddle erase current on, the track width of a data test head is 0.175 + 0.005, -0.010 mm (0.0069 + 0.0002, -0.004 inches). When measured at the head cable connector, the resonant frequency of one-half of the center tapped write/read coil of acceptable amplitude test heads must be 2.0 megahertz, or greater; while that of acceptable data heads must be 4.2 megahertz, or greater. Methods of measuring the characteristics of track width, resolution, and resonant frequency are described in Appendix C.

Every disk surface in the pack has an associated head. Heads are flown in pairs diametrically positioned on opposite sides of each disk. Space limitations require that the heads are displaced on either side of a radial line to the center of rotation. The heads move in and out on a line of access parallel to this radial. Four different head designs (A-up, A-down, B-up, and B-down) are needed because of these position requirements. The head write gaps are radial to the center of rotation at only one track location. The write gaps have an increasingly positive or negative skew angle to the radial on either side of that track.

The flying height of the head is determined by its aerodynamic design, the surface velocity, the physical characteristics of the disk surface, the head-load force, and the temperature and humidity conditions. The amplitude of the head read signal is determined by the head flying height and the frequency of the recorded signal. The read-back signal amplitude decreases as the signal half-wavelength approaches the gap length dimension of the read head. It has been found that the read-back characteristics between the same type test heads of a given manufacturer may vary as much as 20 percent when writing with tunnel erase current on. One reason for these differences between heads may be that the read/write and the tunnel/straddle erase winding assemblies are manually installed in the head pad during the manufacturing process. The differences in the characteristics between heads are somewhat less when writing with the tunnel erase current off.

3.3. The Disk Test Bed

a. The Mechanical System

The ANSI and ISO standards for the various types of disk packs specify the required mechanical and electrical characteristics of the test bed to be used for measuring and

calibrating disk surfaces. The NBS test bed used for calibrating low and medium density surfaces is the Applied Magnetics Corporation Model HTU-210 2AB tester. It has been specifically designed to meet these requirements. The mechanical assembly consists of a precision spindle, a fixed speed 2400 ± 24 rpm motor, a precision head loading and actuating mechanism, an electromechanical control panel, and is equipped for mounting industry-compatible IBM 1316 and IBM 2316 type disks and 2316 and 2314 type heads. A permanent magnet assembly is used to provide dc erase for the disk surfaces. The heads can be moved to any desired track position by means of a track counter unit. Calibrated head load forces can be set to a net loading force of 3.43 ± 0.10 newtons (350 ± 10 grams) by means of precision gram gauges. The total head loading force, including head spring tension, is 3.73 ± 0.10 newtons (380 ± 10 grams). The disk surface is supported on the test bed at both the inner and outer diameters. Test heads are flown from above the top surface only, with the direction of rotation of the spindle being selected to maintain proper direction relationship when using "up" or "down" type heads. Reference to this particular test bed is for informational purposes only and does not imply any endorsement by the National Bureau of Standards. Any equivalent type test bed that meets the mechanical and electrical requirements may be used.

b. The Write Channel

The block diagram of the write channel operation of the NBS disk measurement system is shown in figure 1. Front panel control switches give the operator the options of selecting the proper write current level, write frequency, and tunnel/straddle erase currents for the various testing conditions. The WRITE 1/READ mode is used when calibrating disk surfaces. In this mode, upon pressing the START switch, a dc erase operation is performed during the first revolution, writing takes place during the second revolution, and continual reading occurs on successive revolutions. Appropriate type read/write driver circuit cards are employed for using either amplitude or data test heads. When driving an applicable dummy resistive load, the balanced current driver is capable of switching the write current between its two outputs in less than 75 nanoseconds when the 2311 driver card is selected, and less than 25 nanoseconds when the 2314 driver card is selected. Appendix C describes the applicable resistive load. The write current waveform may be observed from the output of a current transformer. This transformer consists of a one turn loop around a lead to one end of the write head winding. The write current waveforms for both amplitude and data test heads meet the characteristic requirements as shown in figure 2. These write current waveforms are specified in national and international disk pack standards. Saturation recording technique is employed. The tunnel/straddle erase current is 40 mA dc. The write current of the 2316 amplitude head is 35 mA for all tracks. When using the 2314 data head, tracks 000 through 127 are written with 35 mA of write current, and tracks 128 through 200 are written with 30 mA of write current. Three basic frequencies are used for calibrating low and medium density surfaces. The 1F frequency is 0.625 MHz (1.25 megatransitions per second), the 2F frequency is 1.25 MHz (2.5 megatransitions per second), and the 4F frequency is 2.5 MHz (5.0 megatransitions per second). The physical location of type A and type B heads with respect to the line of access and the radial to the center of rotation is important in order that the read/write gaps display proper skew angle. Figure 3 shows the physical location of heads on the test bed. Track 000 (R_2) is located 166.726 mm (6.54 ± 0.010 inches) from the center of rotation, and track 200 (R_1) is located 115.062 ± 0.25 mm (4.530 ± 0.010 inches) from the center of rotation.

c. The Read Channel

The block diagram of the read channel of the NBS test bed is shown in figure 4. When measured at the head termination connector, the amplitude test heads see a differential input impedance at the read amplifier of 7500 ohms resistance in parallel with a capacitance of approximately 45 picofarads. Data test heads see a differential input impedance at the read amplifier of 3000 ohms resistance in parallel with a capacitance of approximately 20 picofarads. The input read amplifier has a gain of 100, and a bandwidth that is flat within ± 3% in the frequency range from 300 kilohertz to 4.0 megahertz. The output of the read amplifier goes to an oscilloscope and to the Calibration Factor Correction Unit. The Calibration Factor Correction Unit contains five precision potentiometer networks. The output of each potentiometer is "And gated" with switched dc signals which are selected by TRACK and FREQUENCY or switch settings. The output of the Calibration Factor Correction Unit goes to a Digital Read Out Unit.

The Digital Read Out Unit contains a post amplifier, peak detector and buffer, sample-and-hold, scaling network, and a digital voltmeter for visual readout. The analog read head

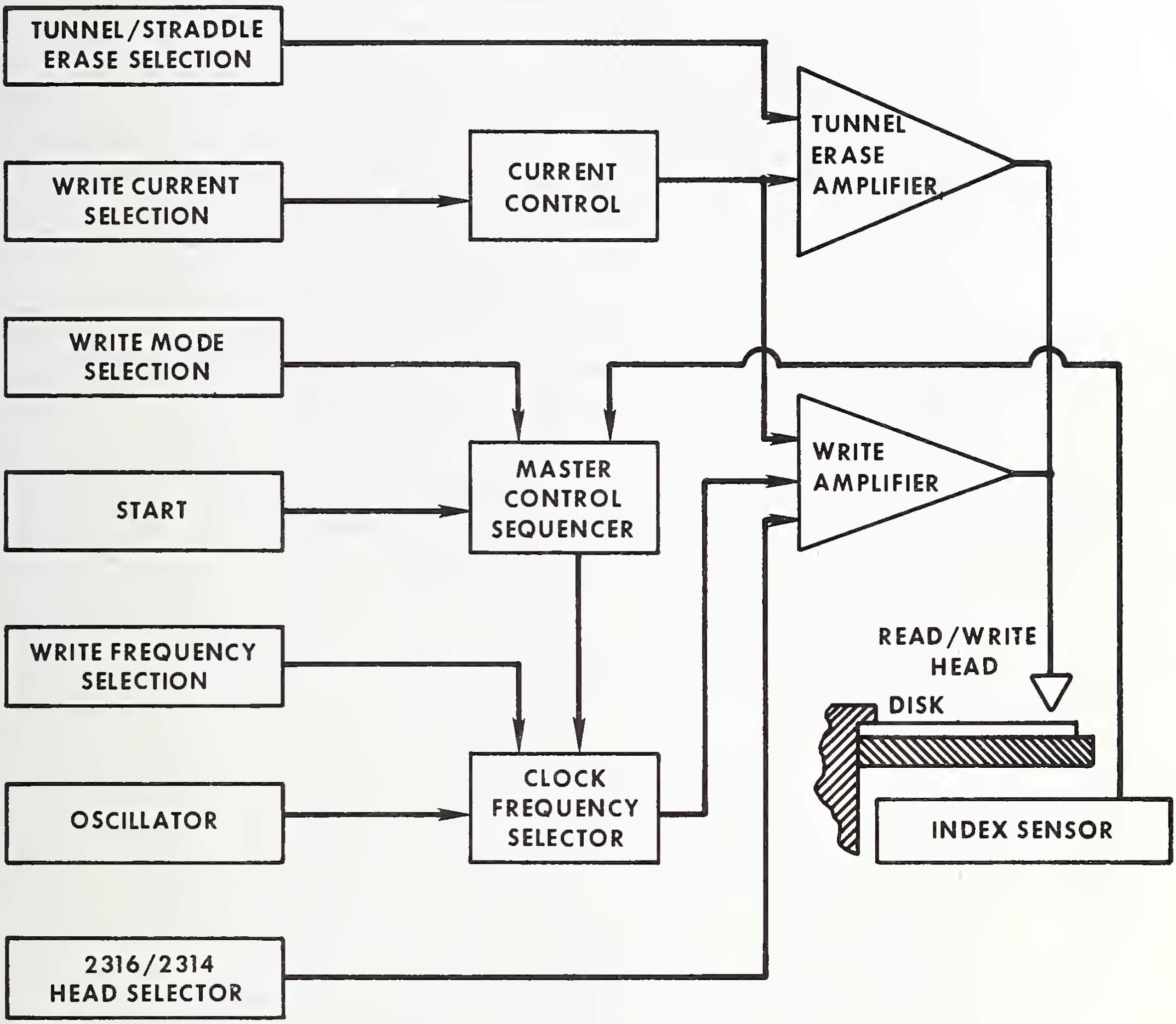
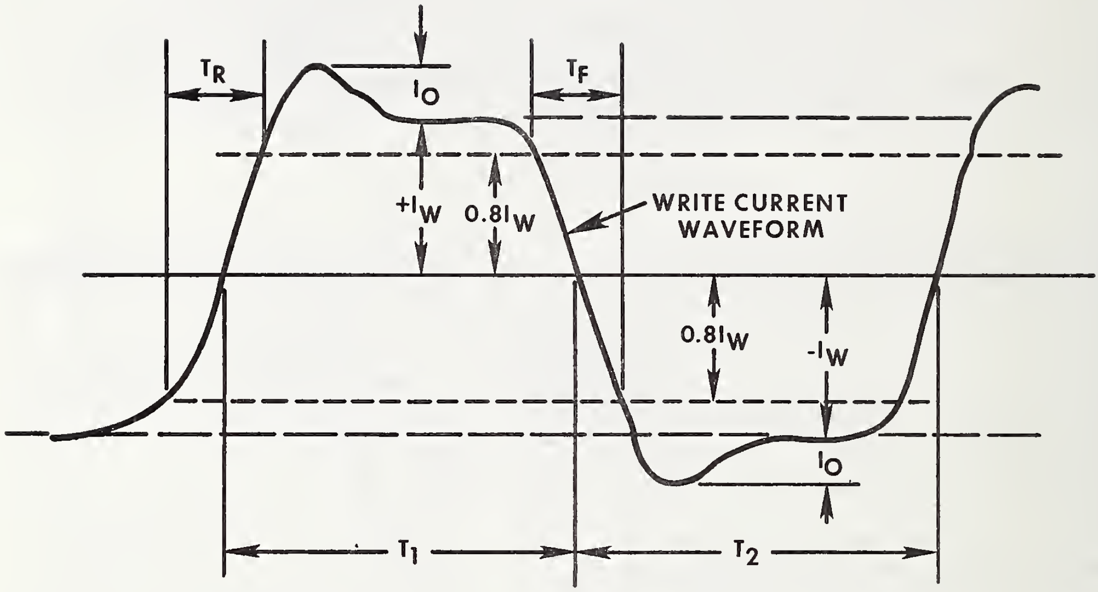


FIGURE 1. BLOCK DIAGRAM OF THE WRITE CHANNEL



	2316 AMPLITUDE TEST HEADS	2314 DATA TEST HEADS
I_W	35±1 mA (ALL TRACKS)	35±1 mA (TRACK 000)
		30 ±1 mA (TRACK 200)
I_O	≤10% I_W	≤8% I_W
T_R	170±30 NANOSECONDS	140±20 NANOSECONDS
T_F	170±30 NANOSECONDS	140±20 NANOSECONDS
$T_R=T_F$	±20 NANOSECONDS	±20 NANOSECONDS
$T_1=T_2$	±2%	±2%

FIGURE 2. WRITE CURRENT WAVEFORM

TYPE HEAD	F_{ar}	F_{br}
DATA	12.125mm (0.4774")	10.987 mm (0.4326")
AMPLITUDE	11.999 mm (0.4724")	10.861 mm (0.4276")

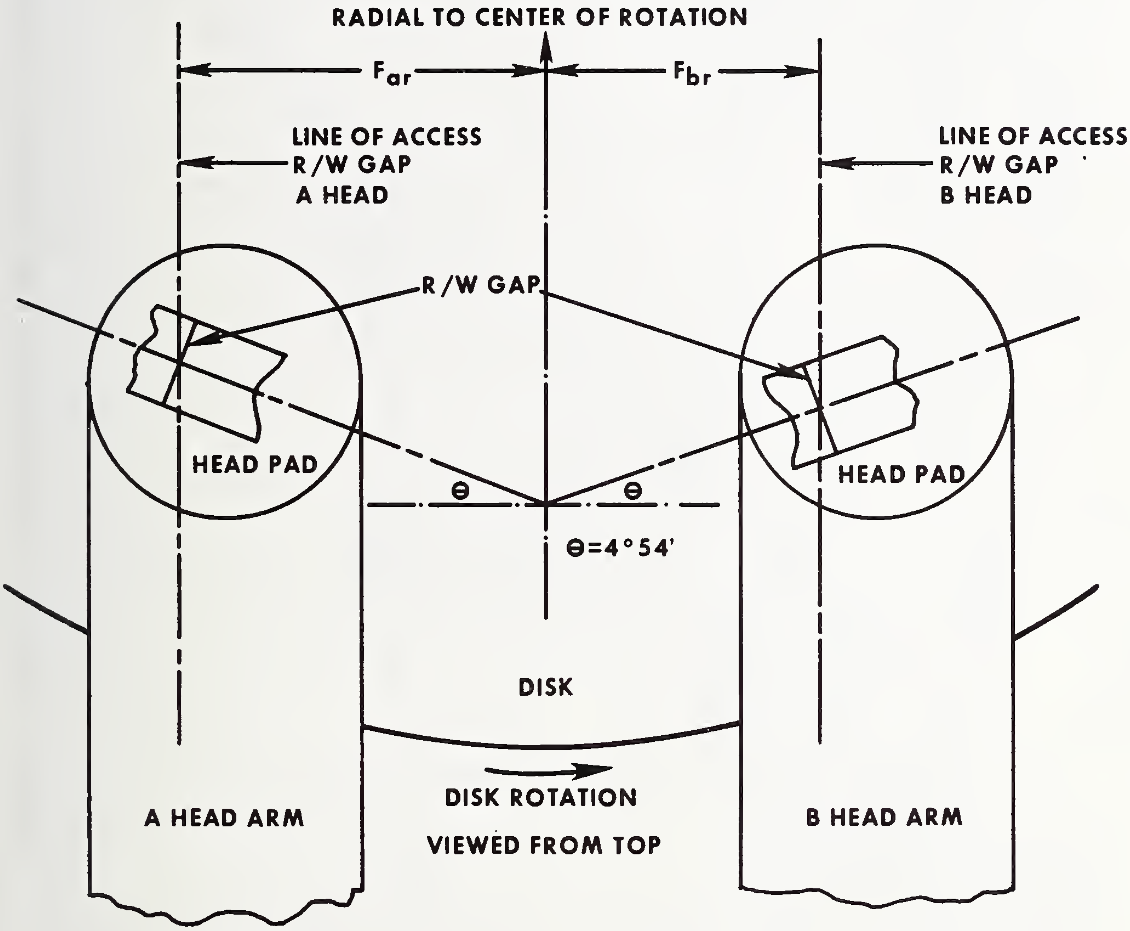


FIGURE 3. GEOMETRY OF HEAD DISK SYSTEM

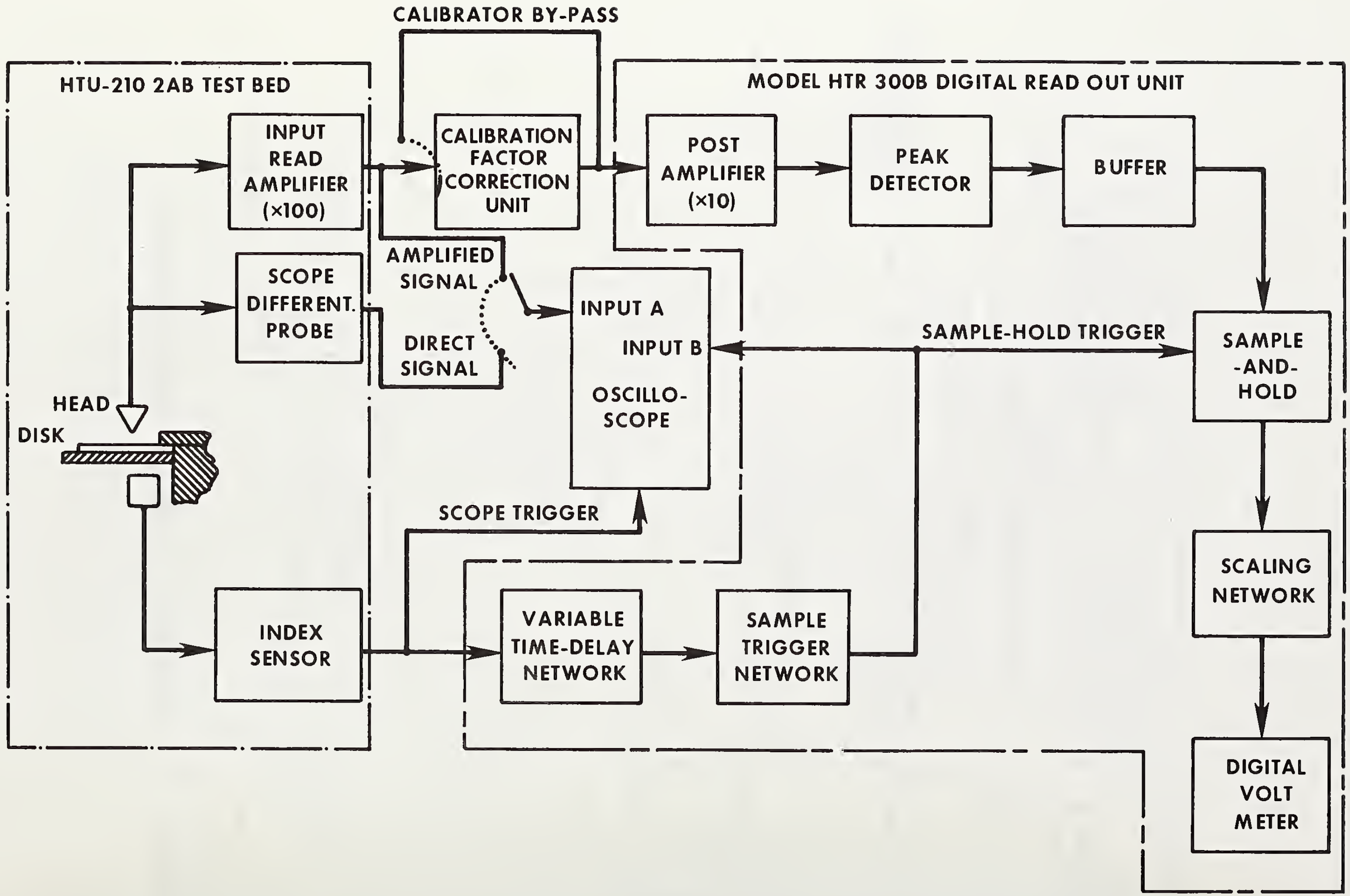


FIGURE 4. BLOCK DIAGRAM OF THE READ CHANNEL

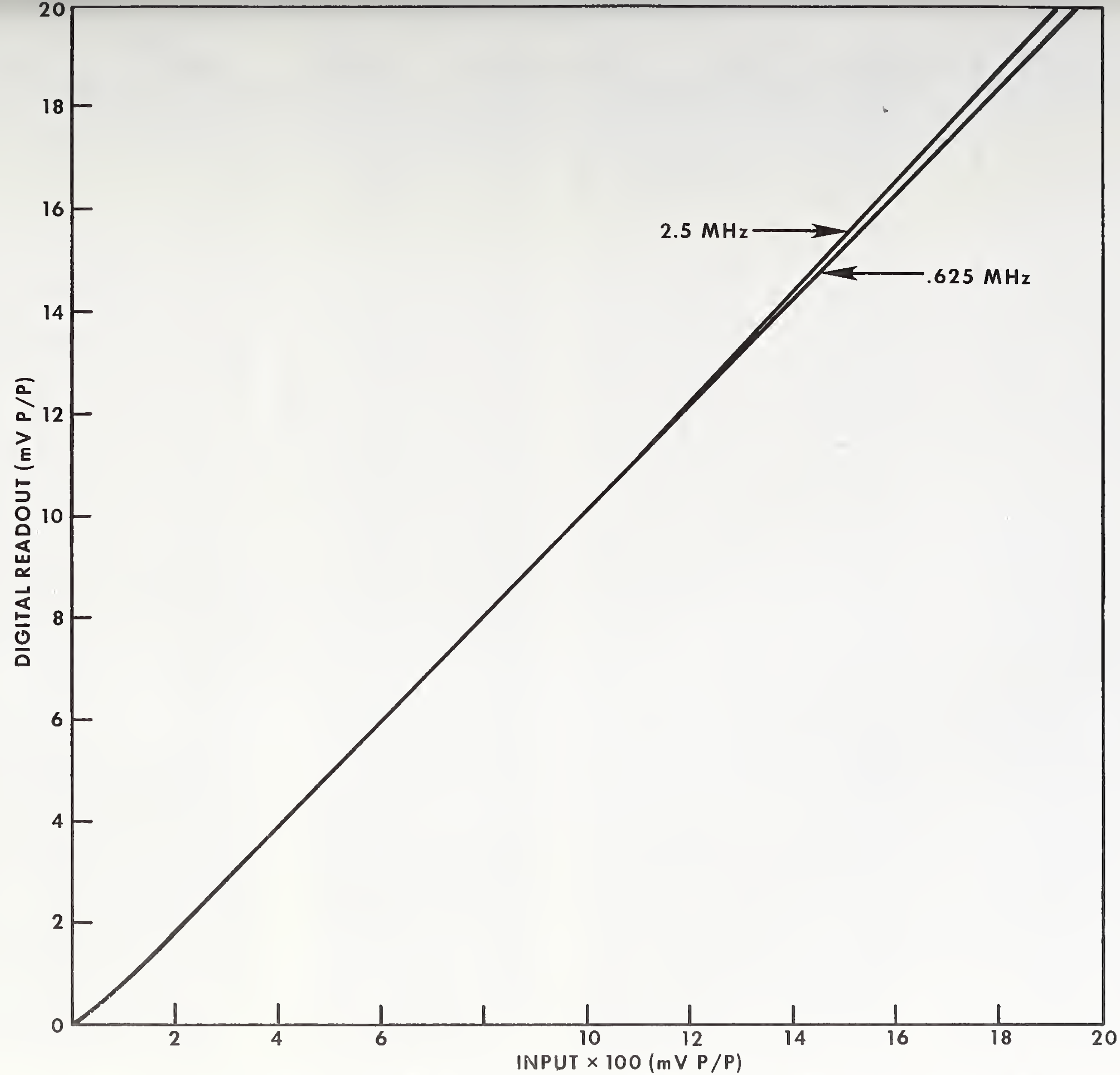


FIGURE 5. CORRECTION CURVE FOR THE DIGITAL READ-OUT UNIT

signal from the input amplifier is first amplified by the post amplifier which has a gain of 10, and is then peak detected. The peak detector has a very fast charge time and a very slow discharge time. The detector senses the higher peaks of the analog signal, and misses very low amplitude pulses. The output of the detector is sample-and-held once every revolution of the disk. The sample time is triggered by an index sensor at the spindle, and is adjustable over 85 percent of a disk revolution by means of a variable time delay network. The sample time is 60 microseconds in duration, at the end of each sample time the instantaneous level of the sampled signal is held until the next sample time. The sample-and-hold output goes through a scaling network into a digital voltmeter for visual readout. The system noise of the digital voltmeter is less than 0.20 mV as displayed. The Digital Read Out Unit response is not exactly linear with respect to signal amplitude and frequency. The output reading of the digital voltmeter must therefore be corrected according to the correction curve as shown in figure 5.

The "Measured Amplitude" of the read signal is the actual peak-to-peak signal amplitude value averaged over the measured area, when recorded in accordance with given test conditions. The measured areas are located by scribe marks on the surface of the disk at R_1 and at R_2. The measured areas begin 50 microseconds after the trailing edge of the scribe mark and extend 225 microseconds in length, with the disk rotating at 2400 rpm. The scribe mark produces a discontinuity of the surface magnetic media. The result of the scribe mark is readily observed on the oscilloscope as a pair of positive and negative pulses. The TIME DELAY potentiometer to the sample-and-hold circuit can be adjusted so that the trailing edge of the sample-and-hold trigger occurs simultaneously with the scribe mark as displayed on the oscilloscope. Under these conditions, the value displayed by the digital voltmeter is a measure of the average peak-to-peak read head signal produced during the first 60 microseconds of the measured test area. Five additional time delay steps to the trigger pulse can be inserted by the TEST AREA switch on the Read Out Unit in order to allow read-out observations of five discrete areas within the 225 microsecond test area. Calculations are then made of these five observations to determine the average Measured Amplitude of the test area.

The Measured Amplitude of the candidate disk test area is used in calculating the Calibration Factor. The Standard Reference Surface and test head are first put on the disk test bed. The appropriate Calibration Factor Correction Unit potentiometer is then preadjusted to produce a readout on the digital voltmeter, when averaged over the test area, that is the Standard Amplitude Reference value for that condition of track and frequency. The candidate disk is then substituted in place of the Standard Reference Surface, and the Measured Amplitude is then observed. The setting of the Calibration Factor Correction Unit is left unchanged during this operation. The Calibration Factor for the candidate disk is then calculated as being the ratio of the Standard Amplitude Reference to that of the value of Measured Amplitude of the candidate disk.

4. The Disk Calibration Procedure

The equipment that is used in the NBS laboratory for calibrating low and medium disk surfaces consists of an Applied Magnetics Corporation (AMC) Model HTU-210 2AB test bed, AMC Model HTR-300 B Digital Read Out Unit, AMC Model CFC-210 Disk Calibration Factor Correction Unit, Renco Model R3-S counter (used for counting track position), and a Tektronix Model 545 oscilloscope with a dual input 1A5 plug-in unit. Switch names are capitalized in the operating procedure description that follows. HEAD SELECT switches are located on both the HTU-210 2AB test bed and the Disk Calibration Factor Correction Unit. The front panel of the test bed also contains the following switches: TRACK, FREQUENCY, WRITE CURRENT, MODE, and TUNNEL/STRADDLE ERASE. The Calibration Factor Correction Unit also contains a CALIBRATE/BYPASS switch and the following potentiometers: TRACK 000 1/2F, TRACK 200 1F, TRACK 000 1F, and TRACK 200 2F. The CALIBRATE/BYPASS switch is normally left in the calibrate position. The Read Out Unit contains a five position TEST AREA switch and a TIME DELAY potentiometer. Reference to the particular test equipment used is for informational purposes only and does not imply any endorsement by the National Bureau of Standards. Any equivalent type test equipment may be used.

All electrical power to the equipment should be applied at least one-half hour before taking any measurements in order to allow the operating temperature to stabilize. The operating laboratory temperature should be 23° ± 3°C (73° ± 5°F), and the relative humidity should be in the range between 40 percent and 60 percent. The analog signal output of the read amplifier is connected to one input of the plug-in unit of the oscilloscope, and the

sample trigger pulse of the Read Out Unit connected to the other input. This is done in order to accurately position the observation points within the test area. Set the Track Counter to 000, with the test bed positioned so that the head position dial indicator reads 0. All of the disks and heads should be acclimatized for at least 24 hours under ambient laboratory temperature and humidity conditions before initiating the calibration procedure. The test bed, disks, and heads should all be wiped clean before each measurement with a solution of 91 percent alcohol and 9 percent water by volume.

4.1. Calibration Procedure for Low Density Surfaces

(1) Placement of the Standard Reference Surface on the NBS test bed:

(a) Place the Low Density Standard Amplitude Reference Surface and the 2316 amplitude test head on the test bed.
(b) Load the head onto the disk with 350 grams of net load force.
(c) Position the head to track 000.

(2) Switch Settings:

(a) WRITE CURRENT 35 mA,
(b) TUNNEL ERASE on,
(c) WRITE FREQUENCY 0.625 MHz,
(d) MODE write 1/read,
(e) TRACK 000,
(f) HEAD SELECT 2311.

(3) Oscilloscope Adjustments:

(a) TEST AREA switch to 0.
(b) Adjust TIME DELAY potentiometer until the trailing edge of the sample trigger pulse occurs at the same time as the scribe mark. (This can be observed on the oscilloscope.)

(4) Calibrating the NBS test bed at 1/2F test conditions:

(a) Press the START button.
(b) Adjust the TRACK 000 1/2F potentiometer so that the average value displayed by the digital voltmeter is 11.3 mV. (This adjustment should be made while switching the TEST AREA switch to each one of its five positions.)
(c) Position the head to track 200.
(d) Position the TRACK switch to 200.
(e) Repeat step 3.
(f) Press the START button.
(g) Adjust the TRACK 200 1/2F potentiometer in the manner that is described in step (4.b) so that the average value displayed by the digital voltmeter is 6.6 mV.

(5) Calibrating the NBS test bed at 1F test conditions:

(a) Position the WRITE FREQUENCY switch to 1.25 MHz.
(b) Press the START button.
(c) Adjust the TRACK 200 2F potentiometer in the manner that is described in step (4.b) so that the average value displayed by the digital voltmeter is 3.5 mV.

(6) Candidate Disk Calibration at 1/2F test conditions:

(a) Substitute the candidate disk in place of the Low Density Standard Amplitude Reference Surface.
(b) Load the head onto the disk with 350 grams of net load force.
(c) Position the FREQUENCY switch to 0.625 MHz.
(d) Position the TRACK switch to 000. (From this point on, do not change the settings of the potentiometers from those obtained during steps 4, 5.)
(e) Position the head to track 000.
(f) Repeat step 3.
(g) Press the START button.

(7) Calculation of Calibration Factor for Test A: Calculate the average value of the five readings displayed on the digital voltmeter that are obtained when switching the TEST AREA switch to each one of its five positions. This calculated average value is the Measured Amplitude of the candidate disk for low density Test A conditions. The Calibration Factor (C_D) of the candidate low density disk for Test A is then calculated according to the following equation:

$$\text{Test A:}\quad C_D = \frac{\text{Standard Amplitude Reference (11.3 mV)}}{\text{Measured Amplitude of candidate disk (mV)}}$$

(8) Calculation of Calibration Factor for Test B: Position the head to track 200. Position the TRACK switch to 200. Repeat step 3. Press the START button. Calculate the average value of the five readings displayed on the digital voltmeter that are obtained when switching the TEST AREA switch to each one of its five positions. This calculated average value is the Measured Amplitude of the candidate low density disk for Test B conditions. The Calibration Factor (C_D) of the candidate low density disk for Test B is then calculated according to the following equation:

$$\text{Test B:}\quad C_D = \frac{\text{Standard Amplitude Reference (6.6 mV)}}{\text{Measured Amplitude of candidate disk (mV)}}$$

(9) Calculation of Calibration Factor for Test C: Position the WRITE FREQUENCY to 1.25 MHz. Press the START button. Calculate the average value of the five readings displayed on the digital voltmeter that are obtained when switching the TEST AREA switch to each one of its five positions. This calculated average value is the Measured Amplitude of the candidate low density disk for Test C conditions. The Calibration Factor (C_D) of the candidate low density disk for Test C is then calculated according to the following equation:

$$\text{Test C:}\quad C_D = \frac{\text{Standard Amplitude Reference (3.5 mV)}}{\text{Measured Amplitude of candidate disk (mV)}}$$

4.2. Calibration Procedure for Medium Density Surfaces

a. Amplitude Reference Calibration

(1) Placement of the Standard Reference Surface on the NBS test bed:

(a) Place the Medium Density Standard Amplitude Reference Surface and the 2316 amplitude test head on the test bed.
(b) Load the head onto the disk with 350 grams of net load force.
(c) Position the head to track 000.

(2) Switch settings:

(a) WRITE CURRENT 35 mA,
(b) TUNNEL ERASE off,
(c) WRITE FREQUENCY 0.625 MHz,
(d) MODE write 1/read,
(e) TRACK 000,
(f) HEAD SELECT 2311.

(3) Oscilloscope adjustment:

(a) Position the TEST AREA switch to 0.
(b) Adjust the TIME DELAY potentiometer until the trailing edge of the sample trigger pulse occurs at the same time as the scribe mark. (This can be observed on the oscilloscope.

(4) Calibrating the NBS test bed at 1/2F test conditions:

(a) Press the START button.

(b) Adjust the TRACK 000 1/2F potentiometer so that the average value displayed by the digital voltmeter is 11.5 mV. (This adjustment should be made while switching the TEST AREA switch to each one of its five positions.)

(c) Position the head to track 200.

(d) Position the TRACK switch to 200.

(e) Repeat step 3.

(f) Press the START button.

(g) Adjust the TRACK 200 1/2F potentiometer in the manner that is described in step (4.b) so that the average value displayed by the digital voltmeter is 7.0 mV.

(5) Candidate Disk Calibration at 1/2F test conditions:

(a) Substitute the candidate disk in place of the Medium Density Standard Amplitude Reference Surface.

(b) Load the head onto the disk with 350 grams of net load force.

(c) Position the TRACK switch to 000. (From this point on, do not change the settings of the potentiometers from those obtained during steps 4 and 5.)

(d) Position the head to track 000.

(e) Repeat step 3.

(f) Press the START button.

(6) Calculation of Calibration Factor for Test A: Calculate the average value of the five readings displayed on the digital voltmeter that are obtained when switching the TEST AREA switch to each one of its five positions. This calculated average value is the Measured Amplitude of the candidate disk for medium density Test A conditions. The Calibration Factor (C_{AD}) of the candidate medium density disk for Test A is then calculated according to the following equation:

$$\text{Test A:}\quad C_{AD} = \frac{\text{Standard Amplitude Reference (11.5 mV)}}{\text{Measured Amplitude of candidate disk (mV)}}$$

(7) Calculation of Calibration Factor for Test B: Position the head to track 200. Position the TRACK switch to 200. Repeat step 3. Press the START button. Calculate the average value of the five readings displayed on the digital voltmeter that are obtained when switching the TEST AREA switch to each one of its five positions. This calculated average value is the Measured Amplitude of the candidate disk for medium density Test B conditions. The Calibration Factor (C_{AD}) of the candidate medium density disk for Test B is then calculated according to the following equation:

$$\text{Test B:}\quad C_{AD} = \frac{\text{Standard Amplitude Reference (7.0 mV)}}{\text{Measured Amplitude of candidate disk (mV)}}$$

b. Data Reference Calibration

(1) Placement of Standard Reference Surface on the NBS test bed:

(a) Place the Medium Density Standard Data Reference Surface and the 2314 data test head on the test bed.

(b) Load the head onto the disk with 350 grams of net load force.

(c) Position the head to track 200.

(2) Switch settings:

(a) WRITE CURRENT 30 mA,

(b) STRADDLE ERASE on,

(c) WRITE FREQUENCY 1.25 MHz,

(d) MODE write 1/read,

(e) TRACK 200,

(f) HEAD SELECT 2314

(3) Oscilloscope adjustment:

(a) Position the TEST AREA switch to 0.
(b) Adjust the TIME DELAY potentiometer until the trailing edge of the sample trigger pulse occurs at the same time as the scribe mark. (This can be observed on the oscilloscope.)

(4) Calibrating the NBS test bed at 1.25 megahertz test conditions:

(a) Press the START button.
(b) Adjust the TRACK 200 1/2F potentiometer so that the average value displayed by the digital voltmeter is 3.8 mV. (This adjustment should be made while switching the TEST AREA switch to each one of its five positions.)

(5) Calibrating the NBS test bed at 2.5 megahertz test conditions:

(a) Position the WRITE FREQUENCY switch to 2.5 MHz.
(b) Press the START button.
(c) Adjust the TRACK 200 1F potentiometer in the manner that is described in step (4.b) so that the average value displayed by the digital voltmeter is 1.5 mV.

(6) Candidate disk calibration at 1F test conditions:

(a) Substitute the candidate disk in place of the Medium Density Standard Data Reference Surface.
(b) Load the head onto the disk with 350 grams of net load force.
(c) Position the head to track 200.
(d) Position the FREQUENCY switch to 1.25 MHz. (From this point on, do not change the settings of the potentiometers from those obtained during steps 4 and 5.)
(e) Repeat step 3.
(f) Press the START button.

(7) Calculation of Calibration Factor for Test C: Calculate the average value of the five readings displayed on the digital voltmeter that are obtained when switching the TEST AREA switch to each one of its five positions. This calculated average value is the Measured Amplitude of the candidate disk for medium density Test C conditions. The Calibration Factor (C_{DD}) of the candidate medium density disk for Test C is then calculated according to the following equation:

$$\text{Test C:}\quad C_{DD} = \frac{\text{Standard Data Reference (3.8 mV)}}{\text{Measured Amplitude of candidate disk (mV)}}$$

(8) Calculation of Calibration Factor for Test D: Position the WRITE FREQUENCY switch to 2.5 MHz. Press START button. Calculate the average value of the five readings displayed on the digital voltmeter that are obtained when switching the TEST AREA switch to each one of its five positions. This calculated average value is the Measured Amplitude of the candidate disk for medium density Test D conditions. The Calibration Factor (C_{DD}) of the candidate medium density disk for Test D is then calculated according to the following equation:

$$\text{Test D:}\quad C_{DD} = \frac{\text{Standard Data Reference (1.5 mV)}}{\text{Measured Amplitude of candidate disk (mV)}}$$

5. Preparation of the Disk Calibration Report

Each disk calibration is repeated nine times for each one of the test conditions. The calibration process is repeated three times with each one of three appropriate type amplitude or data test heads. Any observational or operational errors may be detected and eliminated by means of this process. The calculated average value of the Disk Calibration Factor that is obtained from these repetitive tests is then reported on the Disk Calibration Report form. The forms that are used for Low and Medium Density Disk Calibration Reports

are shown in Appendix A and in Appendix B. The value of the Uncertainty Factor given for each test condition is three times the value of the computed standard deviation. The computed standard deviation is derived from a data base of measurements that is being continually maintained and updated. These measurements are made using a group of primary and working reference surfaces and test heads for low and medium density use. A PDP-11/45 computer has been programmed for calculating and updating the current values of Disk Calibration Factors and Uncertainty Factors that are obtained from this data base.

The assistance of Mr. Sidney B. Geller as technical consultant, of Mr. Michael D. Hogan in maintaining the data base of measurements of reference surfaces and test heads and the calculations for computing Disk Calibration Factors and Uncertainty Factors, and of Mr. William B. Truitt in developing and implementing the computer program that is used for calculating the Disk Calibration Factors and Uncertainty Factors that are derived from this data base is gratefully acknowledged. The assistance of Mrs. Candy Leatherman in the preparation of the manuscript is also gratefully acknowledged. All of the above mentioned personnel are members of the Computer Systems Engineering Division.

Appendix A
LOW DENSITY DISK CALIBRATION REPORT FORM

NBS Magnetic Media Group
Report of Disk Calibration

Test No.:
Date of Test:
Low Density (1100 bpi) Disk:
Submitted by:

TEST	TRACK; FREQUENCY	SAR	CALIBRATION FACTOR (C_D)	UNCERTAINTY FACTOR
A	000; 0.625 MHz	11.3 mV		±.07
B	200; 0.625 MHz	6.6 mV		±.06
C	200; 1.25 MHz	3.5 mV		±.09

NOTES:
1. 2316 Amplitude Type Test Head used with Tunnel Erase Current on.
2. Uncertainty Factor is defined as three times the standard deviation; i.e., 3σ.
3. Calibrated Surface is side of disk inscribed with identifying number and scribes.
4. Calibration Factor defined as:

$$C_D = \frac{\text{Standard Amplitude Reference (SAR)}}{\text{Candidate Measured Signal Amplitude}}$$

PERFORMED BY:

Data Acquisition and Storage Section
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Appendix B
MEDIUM DENSITY DISK CALIBRATION REPORT FORM

NBS Magnetic Media Group
Report of Disk Calibration

Test No.:
Date of Test:
Medium Density (2200 bpi) Disk:
Submitted by:

I. (Using 2316-Amplitude Type Test Head Without Tunnel Erase Current)

TEST	TRACK	FREQUENCY	SAR	CALIBRATION FACTOR (C_{AD})	UNCERTAINTY FACTOR
A	000	0.625 MHz	11.5 mV		±.04
B	200	0.625 MHz	7.0 mV		±.07

II. (Using 2314-Data Type Test Head With Straddle Erase Current On)

TEST	TRACK	FREQUENCY	SAR	CALIBRATION FACTOR (C_{DD})	UNCERTAINTY FACTOR
C	200	1.25 MHz	3.8 mV		±.10
D	200	2.5 MHz	1.5 mV		±.14

NOTES:
1. Uncertainty Factor is defined as three times the standard deviation; i.e., 3σ.
2. Calibrated Surface is side of disk inscribed with identifying number and scribes.
3. Calibration Factor defined as:

$$C_{AD} \text{ or } C_{DD} = \frac{\text{Amplitude or Data Reference (SAR or SDR)}}{\text{Candidate Measured Signal Amplitude}}$$

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Appendix C
MAGNETIC MEASUREMENTS

Track Width

In order to measure the effective track width of a test head, a seven track wide band with track location 200 in the center of the band is erased. Next, when using an amplitude test head, a 0.625 MHz pattern on track 200 is recorded with tunnel erase. When using a data test head, record with straddle erase a 1.25 MHz pattern is recorded on track 200 with straddle erase. Then move the head radially to the disk in increments of 0.0025 mm (0.001 inch) to the left and to the right of track 200 until the read-back signal becomes zero. Determine the read-back signal amplitude at each incremental move, and plot amplitude (Y axis) versus displacement (X axis). The fringing at both ends of the curve is to be ignored. See Appendix D for a typical plot of track width.

Test Head Resolution

To measure the test head resolution, dc erase and subsequently record a 1F frequency pattern with an amplitude test head (2F frequency pattern when using a data test head) in the test area of the Standard Reference Surface, and determine the read-back signal amplitude. Repeat the same procedure with a 2F frequency pattern in the same area (4F frequency pattern when using a data test head). Determine the read back signal amplitude. The ratio of the 2F amplitude over the 1F amplitude (4F amplitude over the 2F amplitude when using a data test head) multiplied by 100 represents the resolution of the test head in terms of percentage values.

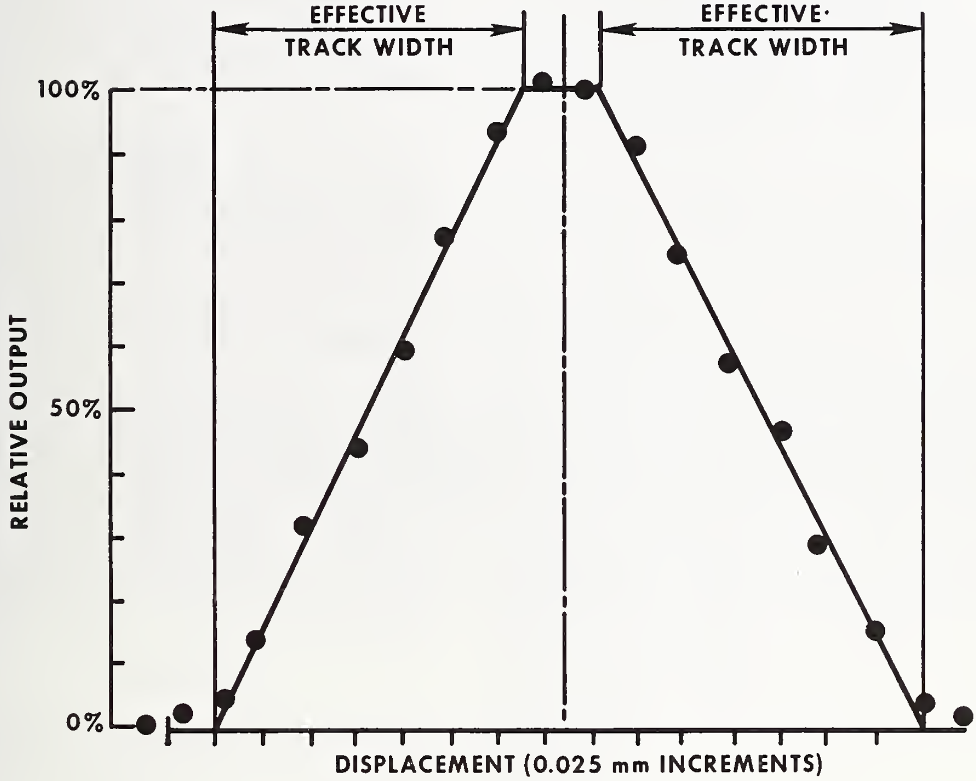
Test Head Resonant Frequency

To measure resonant frequency, the use of a Vector Impedance Meter, Hewlett-Packard Model 4815A or equivalent is suggested. The frequency tuning control is adjusted until the phase angle reads zero. At this point, the resonant frequency of the test head is indicated by the meter.

Write Circuit Dummy Load

The suggested dummy load is two 10 ohm resistors replacing the half coils of the write head.

APPENDIX D TYPICAL TRACK WIDTH DIAGRAM



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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This publication describes the design requirements and the operation of the NBS test bed that is used for calibrating unrecorded magnetic disk pack surfaces for low and medium density use. The signal level calibration is made with respect to a reference level that is derived from the NBS Standard Amplitude and Data Reference Surfaces that are held in repository at NBS. The techniques for calibrating the measurement system with the NBS repository Reference Surfaces and the calibration of candidate reference disks are described in detail.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Calibration Factor; computer amplitude reference; computer storage media; disk calibration; disk pack; magnetic disk; Standard Reference Surface; unrecorded disk surface.

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